Comparative analysis of historical maps of the Canton of Zurich - Switzerland in an interactive online platform

Angeliki Tsorlini, Ionut Iosifescu, Lorenz Hurni

ETH Zurich, Institute of Cartography and Geoinformation, Department of Civil, Environmental and Geomatic Engineering-Zurich, Switzerland

Abstract. Historical maps are a very important part of the World's cultural heritage, offering an image of our past and giving the ability to see the changes taken place in an area over time. For researchers, who are working on the geographic analysis of the environment, the study and the digital comparison of historical and modern maps offer to them a variety of benefits, since it gives them the opportunity to use maps of different time periods to show changes in the environment or in the administrative boundaries of an area or in the names of this area's toponyms. There are additional advantages when this comparison can be done online through a user friendly platform, where all the maps are correctly rectified and aligned to each other. In this way, the user can combine them according to his needs and use them in his study.
In this paper, the methodology for the correct rectification of historical and modern maps is analyzed and the different techniques and tools can be used inside the GeoHistory platform for the digital comparison of maps are described giving much information about their operation. A next step of this research is the automatic regression of the raster historical maps to vector form, which can give the opportunity to detect and determine more easily differences in an area.

Keywords: best fitting process, comparative analysis, historical maps, GeoVITe, GeoHistory, interactive online platform, raster data to vector form

1. Introduction

Historical maps compiled the previous centuries comprise an important part of the cartographic heritage, which offers a variety of benefits and advantages to our modern cartographic science and technology, and to its fu-

ture, enriching and strengthening the interest and concern not only of experts dedicated to Cartography and Maps but also of the society and of the general public (Livieratos 2006). Studying historical maps can be very useful and challenging for researchers, not only for scientists dealing with its practice, but also for those from other scientific areas, such as environmentalists, geologists, geographers, architects. By using a series of maps depicting the same area in different centuries, the scientists can show how this area looked like in the past before the current development took place and can provide a detailed view of changes (physical or cultural) over time.

The wide variety of applications, which historical maps can have in different scientific fields, requires a more accurate approach from the simple digitization of historical maps. Most of the times, it is necessary for the historical maps to come in comparison with each other or with modern maps of the same area in order to show changes in the environment, or the different toponyms of the same place recorded years or even centuries ago, or to study their geometric and projective properties, which are of main interest in the quantitative domain of the history of maps. In order to do that, the researcher is bound to georeference the maps and then to bring them into one to one correspondence, using in both cases best fitting techniques through proper transformations between sets of points, common in both maps. Due to the variety of maps, it is also important for the researcher to make the documentation of each map, separately and to study its geometric properties (Tsorlini et al. 2010, Kousoulakou et al. 2011).

Recently, the development of new technologies and the internet providing web access to information and open data provide the opportunity to researchers to find historical maps correctly registered to a modern reference system since in that way, they can use and combine the maps without having to care about their correct rectification. A portal which can help to this direction is the GeoHistory portal, which is powered by GeoVITe, a project developed by the Institute of Cartography and Geoinformation-IKG in ETH Zurich in cooperation to ETH-Bibliothek to provide its employers, students and researchers from ETH access to professional vector and raster geospatial datasets from the Swiss Federal Office of Topography. Through the GeoHistory portal, a researcher can have online access to historical maps, he can select those referred to the region he needs in order to study and compare them online, he can use different tools to detect and highlight their differences and he can download them in the appropriate format and use them in their study (Iosifescu et al. 2011).

2. Historical Maps of Switzerland

In this project, we have studied five of the most representative historical maps of the Swiss cartography from 17th to 20th cent., focusing on the canton of Zurich. These maps were set in comparison with modern maps and between to each other as well, showing differences during centuries.

The historical maps used in this case are:

- the Hans Conrad Gyger *Map of the Canton of Zurich* (1660),
- the Johann Rudolph Meyer and Heinrich Weiss *Atlas of Switzerland* (1796-1802),
- the Johannes Wild *Topographic Map of the Canton of Zurich* (1852-1865),
- the *Topographic Map of Switzerland* constructed by the Swiss Federal Office of Topography under General Guillaume-Henri Dufour (1845-1864) and
- the *Topographic Atlas of Switzerland* by the Swiss Federal Office of Topography under Colonel Hermann Siegfried (1870-1926).

Apart from these maps, modern maps covering the area of the canton of Zurich were also used for the comparative study of the historical maps, as well as satellite images for the identification of the natural characteristics of the area. These maps, which are already included in GeoVITe portal, were:

- the *Swiss National Map* in scales 1:25000 (1952-1979), 1:50000 (1938-1963) and 1:100000 (1954-1965) and
- the *digital mosaic satellite images Landsat25 and* Spot with high resolution 25 and 5 meters, respectively (2004-2005).

2.1. Map of the Canton Zurich, Hans Conrad Gyger

In 1664/1667, Hans Conrad Gyger (1599-1674), a Swiss cartographer and engineer constructed a map for the area around the city of Zurich. The map was drawn and painted with tempera and it is the oldest known example of a shaded relief of Switzerland. Gyger spent 38 years to paint the map and submitted it to the government of Zurich, which kept it as a secret because of its high military importance.

The map is in scale ca. 1:32000 and it is oriented to the east. It consists of 6 map sheets; the dimensions of each one are ca 110 x 75 cm, composing a map of 220 x 220 cm in size. For the depiction of the area's topography, Gyger used a naturalistic manner of illumination originated from south-west. The map sheet depicting the area around the city of Zurich is presented in *Figure 1*.

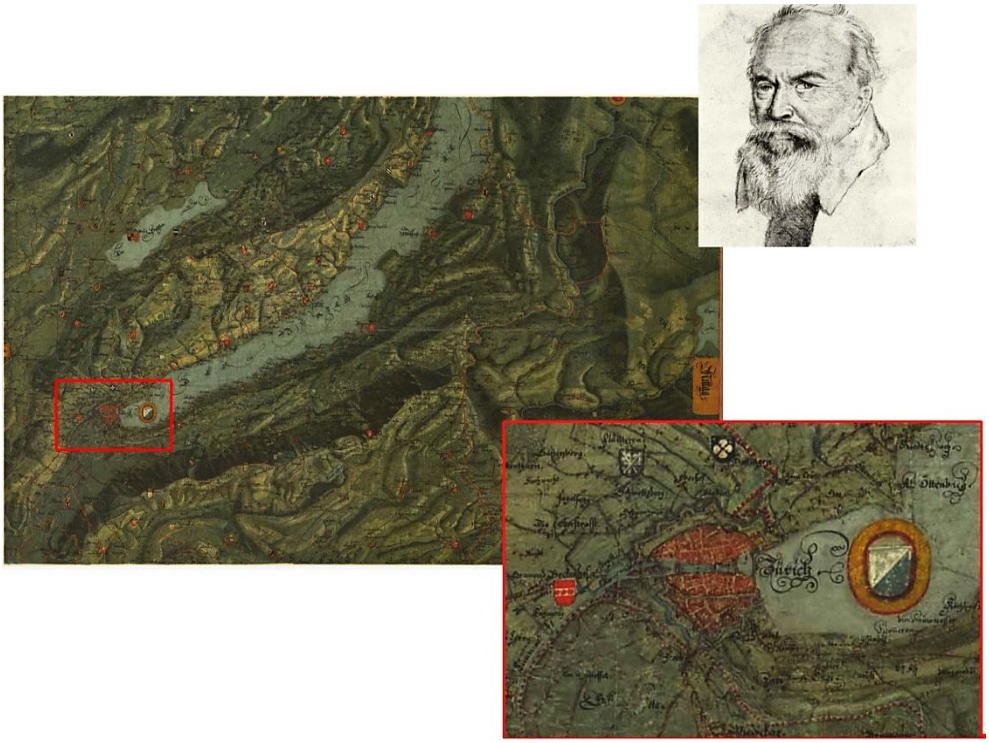

Figure 1. Hans Conrad Gyger Map of the Canton of Zurich, the map sheet depicts the area around the city of Zurich (Source: IKG, ETHZ).

2.2. Atlas of Switzerland, Johann Rudolph Meyer and Heinrich Weiss

The Atlas of Switzerland, known as Atlas Suisse or Meyer-Weiss Atlas, is the oldest map series based on scientific survey and covering the area of Switzerland. The map was created after the decision of the industrialist Johann Rudolf Meyer (1739-1813) from Aarau, who financed the first systematic survey of Switzerland and the map depicting this area. For that purpose, he engaged the Alsatian geometer Johann Heinrich Weiss (1758-1926) to survey the area and the carpenter Joachim Eugen Müller to help them as a guide. The foundations for Meyer's map were baseline measurements by the mathematician Johann George Tralles (1763-1822) and the landscape relief modeling by Müller, after which Weiss drew the map (Pearson et al. 2008).

The result of this work appeared between 1796 and 1802, and included 16 sheets and an overview map (*Figure 2*). Each of the 16 sheets measure 70 cm in width x 51 cm in height and all of them depict Switzerland at a scale

of approximately 1:110000. The Atlas Suisse was the map series with the most accurate coverage of Switzerland for many years, until the appearance of Dufour Map (1845-1865) (Klöti 1997).

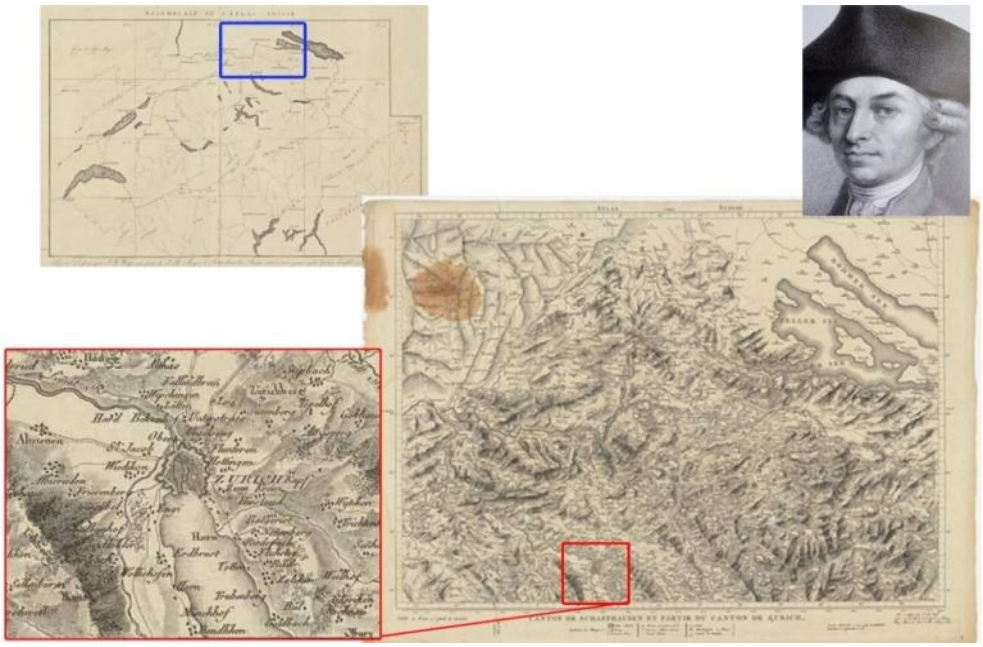

Figure 2. Map Sheet No. 3 of Meyer-Weiss Atlas depicting the area around Zurich (Source: IKG, ETHZ).

2.3. Topographic Map of Canton Zurich, Johannes Wild

The topographic map of the Canton of Zurich in scale 1:25000 (*Figure* 3) is a multicolor, lithograph map, constructed in 32 sheets from 1852 to 1865 by Johannes Wild (1814-1894), an engineer and cartographer, professor of Topography and Geodesy in ETH of Zurich. Since 1833, Wild worked on the construction of a map in scale 1:100000, later coordinated by General Guillaume-Henri Dufour and he participated in the Triangulation, which used as the basis for Dufour Map.

The dimensions of each map sheet are 47 x 30cm, covering the area of 11500 x 7500 meters respectively. The designer of the map was Heinrich Enderli (1828-1872) and the lithographers Josef Graf (1811-1871) and then, Johann Jakob Brack (1824-1867). This map was used later for the construction of Hermann Siegfried's Topographic Atlas of Switzerland, the official map series published by the Federal Topographic Bureau.

Figure 3. The tiling of Wild Map for the Canton of Zurich and the fours sheets covering the area around the city of Zurich (Source: IKG, ETHZ).

2.4. Topographic Map of Switzerland, Guillaume-Henri Dufour

The Topographic Map of Switzerland in scale 1:100000, also known as the *Dufour Map* is the oldest official map series of Switzerland. It was published by the Federal Topographic Bureau under General Guillaume-Henri Dufour from 1845 to 1864 based for the first time on accurate geometric measurements by the Cantons and the Swiss Confederation. The original images for the Dufour Map were created in scale 1:25000 for the Swiss Plateau and Jura mountains and 1:50,000 for Alps Mountains. Ho-wever, the Dufour Map was published in 1:100,000 scale, enabling the territory of Switzerland to be divided into 25 sheets, each of which measured 70 x 48 cm (*Figure 4*).

The geodetic basis used for this map series was the “Schmidt ellipsoid from 1828” and its fundamental point was the old observatory in Bern. The map is drawn in an equal area, untrue conical projection, known as the Bonne projection or as modified Flamsteed projection using the prime Meridian of Paris.

Figure 4. Map Sheet VIII of Dufour Map, entitled “Aarau, Luzern, Zug, Zürich” (Source: IKG, ETHZ).

2.5. Topographic Atlas of Switzerland, Hermann Siegfried

The Topographic Atlas of Switzerland also known as the *Siegfried Atlas* or *Siegfried Map* is an official map series of Switzerland, published by the Federal Topographic Bureau under Colonel Hermann Siegfried from 1870 to 1922. It was based on the original records created for the earlier Dufour Map, however it offered greater precision than it.

It is drawn using a scale of 1:25000 for the Swiss plateau, the French Pre-alps, the Jura Mountains and southern Ticino, and a scale of 1:50000 for other mountain regions and the Swiss Alps, keeping the format of 35 x 24 cm for each sheet in both scales. The map projection’s system is the one used in Dufour Map and its grid is traced every 1500 meters in the map sheets dated before 1913 and every 1000 meters in those dated after 1917.

Until 1949, there were occasional revised editions of Siegfried Map sheets whereas, until 1952 all of them were replaced by the new National Map of Switzerland.

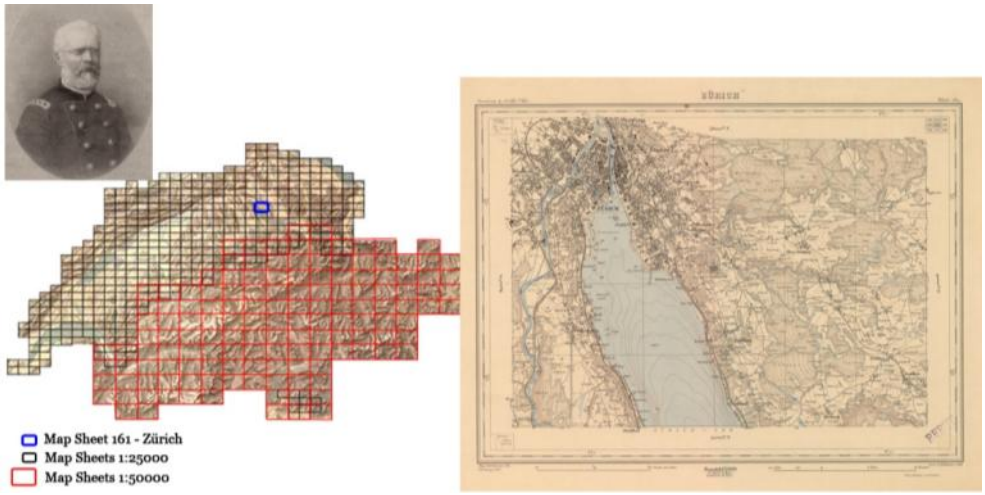

Figure 5. The Tiling of Siegfried Map and the map sheet of Zurich (No. 161) (Source: IKG, ETHZ).

3. Methodology for the correct rectification of the maps

The different time each map is dated, the method used for the depiction of its characteristics and the way it was constructed in association with its internal characteristics, mainly the scale and the projection system are some of the elements which show that each map is unique and should be confronted accordingly, in order to give reliable results during its study. For this reason, the most important thing to be done first is the documentation of the maps.

A specific procedure is followed in order to study the maps and to have them projected to the same reference system and thus, comparable to each other (*Figure 6*). The main steps of this process are (1) the scanning of each historical map, (2) its georeferencing to its projection system -if it is possible- in order to bring it to its physical dimensions and (3) the best fitting of the "georeferenced" map to the modern's map reference system taking local deformations into consideration (Boutoura & Livieratos 1986, 2006).

The *scanning of the maps* is a common procedure, however it is important not to be out of notice, since there are many things which affect the result of the digitization such as the material or the condition of the map (Tsioukas et al. 2006).

In order to bring each historical map to its physical dimensions, eliminating possible geometric deformations induced by scanning, it is important to

georeference them in the projection system they are initially drawn. For the georeference of the historical maps, a grid in the same reference system is used and the historical map is correctly registered to it and thus to its own coordinates. This procedure is implemented for three of the five historical maps studied in this case, namely the map sheets belonging to Wild Map, to Dufour Map and to Siegfried Map but cannot be applied to all the historical maps, since there are maps, usually dated centuries ago, which were not drawn on a particular projection system or they were drawn on a system but it is not obvious which system is this and the bibliographical references cannot help in this direction. Meyer-Weiss Atlas and Gyger Map belong to this category.

In Meyer-Weiss Atlas, the subdivisions of the grid are drawn in the frame of each map sheet, whereas the only grid lines drawn in the map sheets are those of integer degrees, which are very rare, even nonexistent in some sheets. In this case, in order to get an idea about the projection system of the Atlas, we study the map sheet which depicts the whole Switzerland. On this map, the distances between the grid lines of longitude were measured showing that the projection seems to be conical and that its fundamental point should be in Bern but more research should be conducted in order to have more accurate results about this map's projection system. In this study, a conical projection having the prime meridian in Bern is used for the georeference of Meyer-Weiss Atlas map sheets.

On the other hand, on Gyger map, things seem to be simpler, since there is no grid drawn on it or on the frame of the map. This map is regarded as an image and the georeference procedure makes no sense for it, so it is omitted. This map is just best fitted to the final map with which it is going to be compared at the end.

Having the historical maps correctly registered to their coordinates, the next step of the procedure is *to bring them in one to one correspondence with the modern maps* so as to compare their content and to detect changes in the area during centuries. For this reason, the georeferenced historical maps were converted to the modern's map projection system which is the Swiss Grid described by the Swiss oblique conformal cylinder projection and the Bessel ellipsoid of 1841, fixed in position and orientation to the old fundamental point, which is the old observatory in Bern. In that way all the maps are projected in the same reference system giving the opportunity to be compared to each other (Tsorlini et al. 2010).

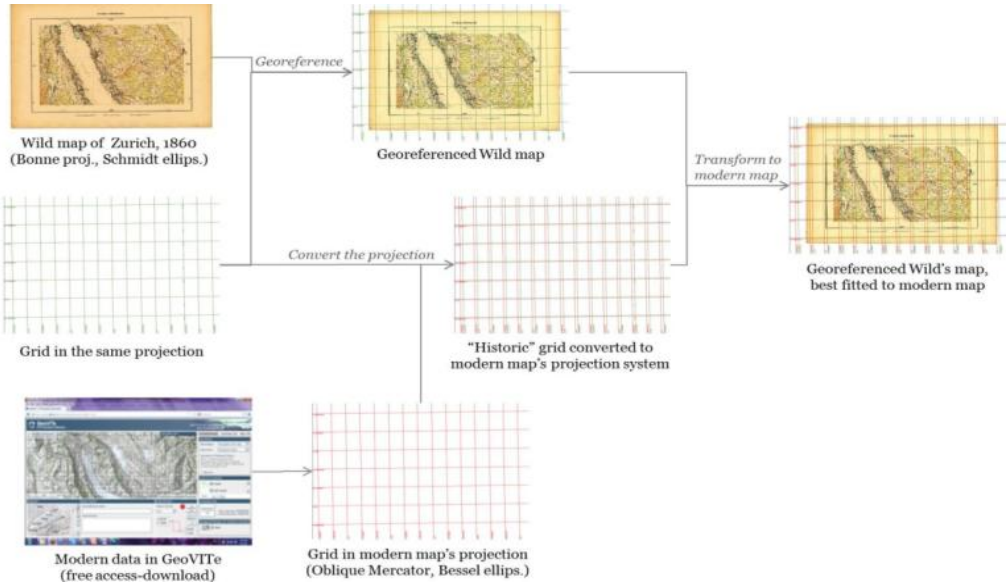

Figure 6. The procedure followed for the correct registration of the scanned historical maps and their digital comparison with modern maps.

4. The GeoHistory portal powered by GeoVITe and its functionalities

The digital combination of historical and modern maps is a very important procedure for researchers and it can offer great benefits to them in the case it can be conducted online through a platform where all the maps are correctly rectified and can be easily compared to each other.

4.1. The GeoVITe and the GeoHistory portals

A service helping in this direction is the GeoHistory portal powered by GeoVITe (Iosifescu et al. 2011), developed to provide online access to historical maps correctly rectified and registered to the current Swiss reference system, through an interface easily accessible and understandable by researchers interested in the comparative analysis of historical maps. This service offers also the opportunity to researchers to compare the historical maps with modern maps through the portal and to find out differences in the environment over the time, contributing in this way to further scientific studies on the development of the landscape and the settlements of the specified area.

The GeoHistory portal uses the basic functionalities developed for GeoVITe portal, but additionally it has some other tools useful for the digital comparison of historical and modern maps. Some of these tools are described below.

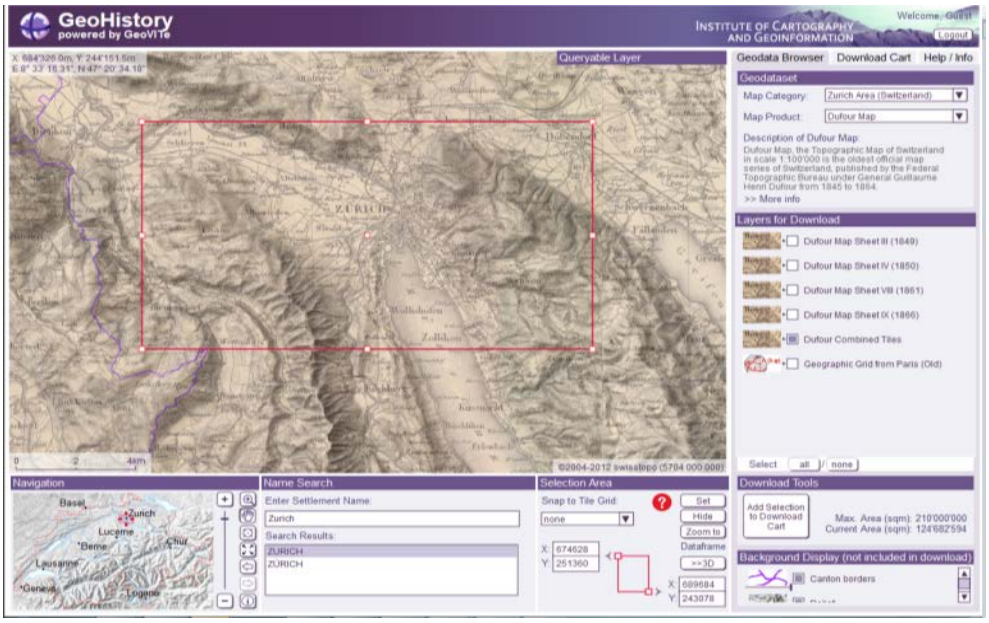

Figure 6. The GeoHistory portal powered by GeoVITe (Source: IKG-ETHZ)

4.2. Digital comparative analysis of maps in GeoHistory portal

Through the GeoHistory portal, it is possible for a researcher to study the geometric and thematic content of a historical map and find more details about its reference system and the relevant grids (geographic or projected) drawn on it (*Figure 7*). This can be done by selecting the appropriate levels from the list on the right.

The online digital comparison of the maps can be done using different techniques according to each researcher's needs and the results of this analysis can be downloaded by ETH users to be further used. The easiest way to compare two maps and to detect the differences between them is to use the transparency technique. For better results, it is possible to invert one of the maps so as the differences to be more obvious (*Figure 8*) or to use vector data included in GeoHistory platform (*Figure 9*). For reliable results, it is important for every comparison to use maps in the same scale.

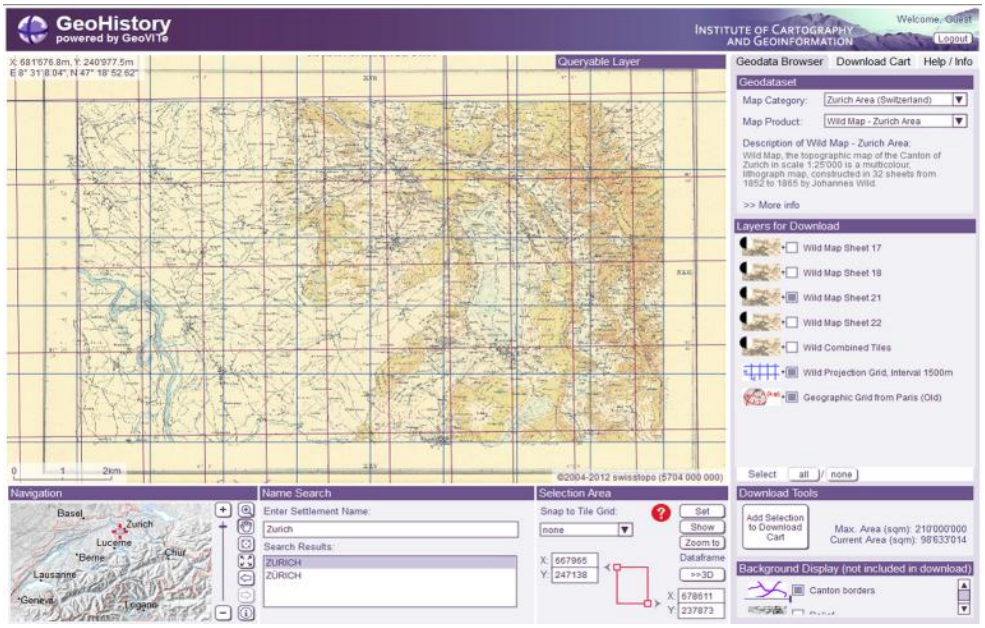

Figure 7. The different layers of Wild map on GeoHistory platform.

Figure 8. Comparing Wild (white lines) and Siegfried (black lines) maps on GeoHistory platform. The areas in grey are those showing no differences.

Figure 9. Detecting differences in buildings depicted on Siegfried map (raster-in black) and on the Swiss National Map (vector-red in transparency).

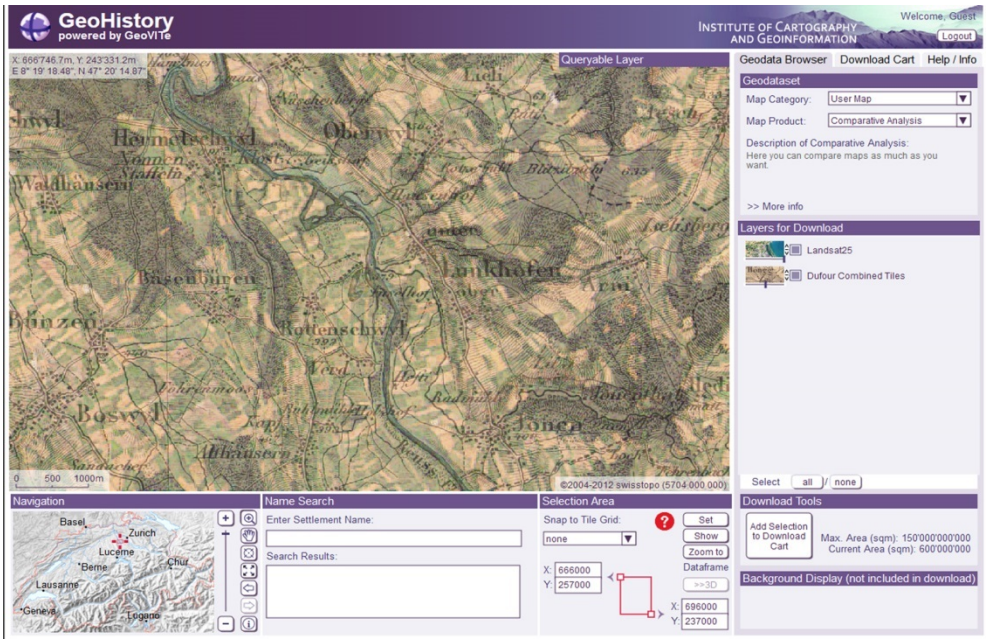

Figure 10. Dufour Map overlaid on Landsat25 showing similarities and differences in the environment.

Another way to identify the changes in the natural characteristics of an area close to the mountains or close to the route of a river is to use the satellite images (*Figure 10*) or the 3D digital model included in the modern data (*Figure 11*) to see if the depiction of these specific areas keeps up with the modern relief.

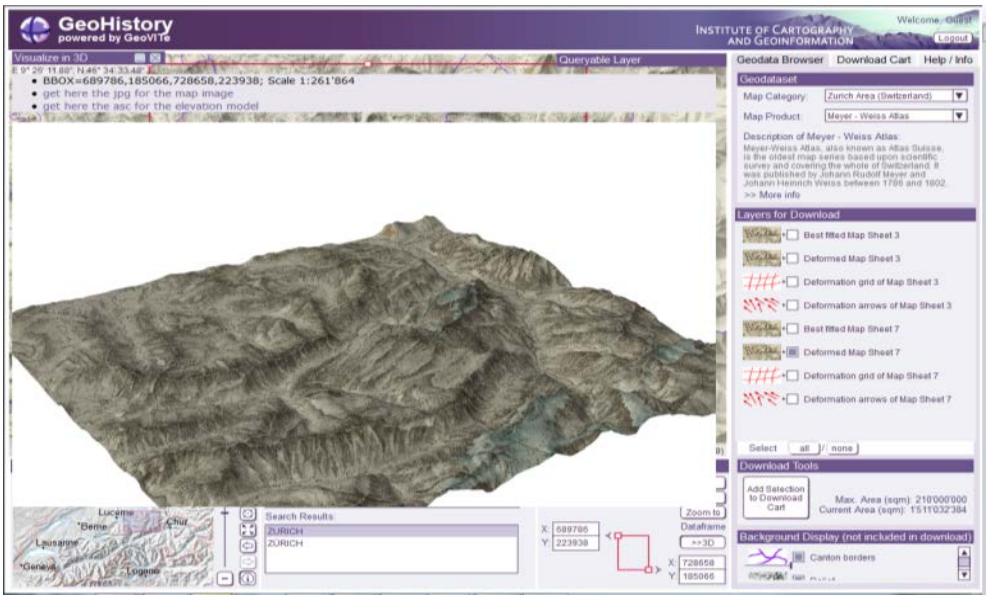

Figure 11. Meyer-Weiss Atlas presented on the 3d model relief of the area around the Canton of Schwyz.

Through the GeoHistory portal, it is possible to study the deformations of the historical maps in comparison to modern data. These deformations can be shown through a grid adjusted to the map and transformed likewise (*Figure 12*) or through arrows showing the magnitude of the deformation on specific places of the map (*Figure 13*). It is also interesting to notice the deformation of the whole map comparing to modern data (Figure 14).

All these techniques applied to historical maps through the GeoHistory platform can benefit researchers, from different scientific areas as well, since they offer them the freedom to decide on their own which technique is the most appropriate to be used in order to show visually better the result of their study.

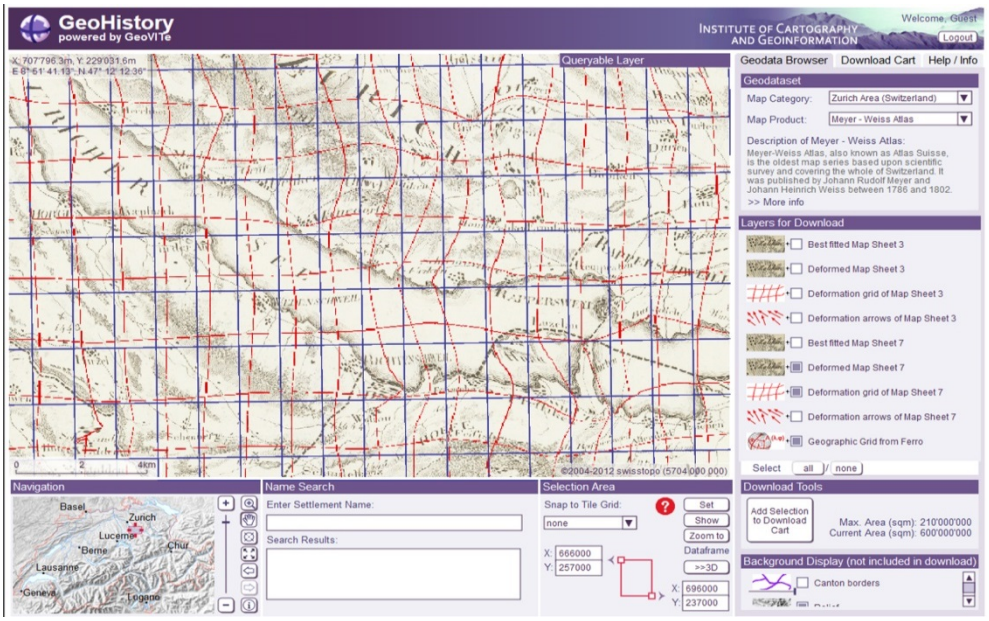

Figure 12. The deformation grid (red) of Meyer-Weiss map in the lake of Zurich. The correct position of the grid is shown in dark blue. The deformation of the map is also obvious in its characteristics.

Figure 13. The deformation arrows of Gyger Map in the area of Zurich compared to the same area in modern maps.

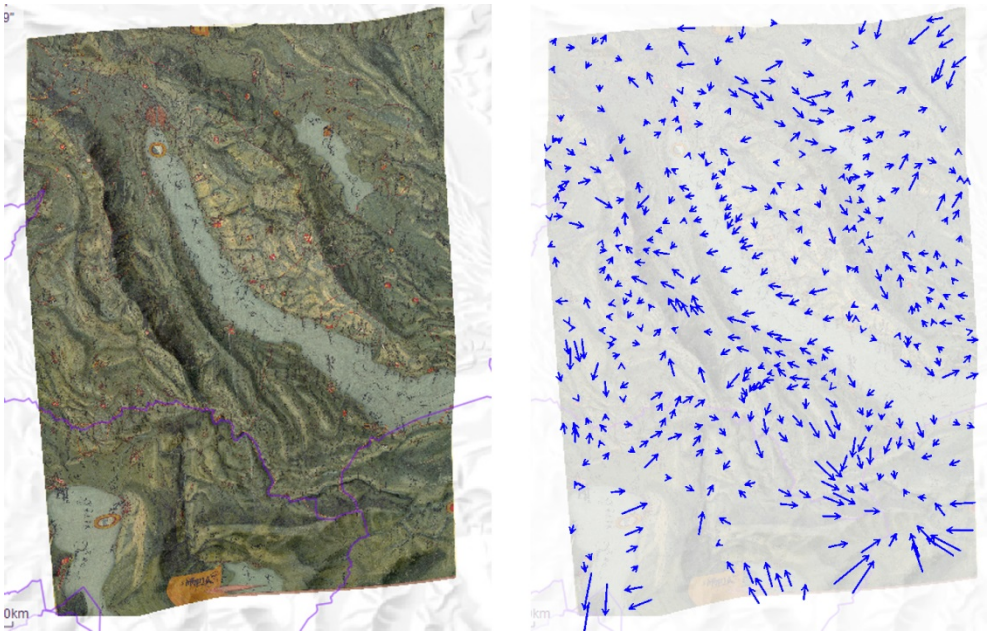

Figure 14. The deformation of Gyger Map sheet in the area of Zurich compared to the same area in modern maps.

5. Conclusion and Future Research

The comparative study of historical maps coming from different time periods, apart from being an educative process in mathematical cartography, is as well important and helpful to many scientists dealing with the geographic analysis of terrain and environmental changes and with the investigation of spatial growth of human activity during the years.

The advances of digital computational and visualization technologies, massively available today allow new approaches and techniques in studying old maps. The transformation of them into digital form, their correct registration and their digital comparison with modern maps online through a platform using new processing methods and technologies offer to researchers many opportunities to enrich their projects with new evidence.

A next step of this research will go beyond the comparative analysis of historical maps and will focus on the automatic conversion of the raster historical maps to vector form. This procedure can give the opportunity to detect and determine more easily differences in an area but it is a challenge to implement it especially to historical maps, since the vectorization of their characteristics is usually difficult due to their design (multicolored, with

shaded relief), their low graphical quality and the amount of data depicted on them.

References

Boutoura C, Livieratos E (1986) Strain analysis for geometric comparisons of maps, The Cartographic Journal, 23:27-34, http://www.ingentaconnect.com/content/maney/caj/1986/00000023/00000001/art00002?crawler=true Accessed 22 March 2013

Boutoura C, Livieratos E (2006) Some fundamentals for the study of the geometry of early maps by comparative methods, e-Perimetron, 1 (1):60-70, http://www.e-perimetron.org/Vol_1_1/Boutoura_Livieratos/1_1_Boutoura_____Livieratos.pdf Accessed 22 March 2013

Dürst A (1990) Die topographische Aufnahme des Kantons Zürich 1843-1851. Cartographica Helvetica 1:2-17. http://dx.doi.org/10.5169/seals-1126. Accessed 20 March 2013

Höhener H-P, Klöti P (2010) Geschichte der schweizerischen Kartographie. Kartographische Sammlungen in der Schweiz, Bern. http://www.zb.unibe.ch/maps/bis/publications/ks/kartographiegeschichte_hoehener_kloeti.pdf Accessed 17 March 2013

Iosifescu C, Iosifescu I, Jenny H, Hurni L (2011) GEOVITE-A service-driven solution for an on demand, user-friendly web access to geodata, 25rd International Cartographic Conference, organized by International Cartographic Association (ICA), Paris, 3-8th August, https://geodata.ethz.ch/geoidea.ro/helpinfo/paper_c.iosifescu_ICC2011_Geovite_submitted.pdf Accessed 17 March 2013

Jenny B (2006) Analysis of the planimetric accuracy of historical maps with digital tools, Proceedings of the 1st international workshop on Digital Approaches to Cartographic Heritage, Thessaloniki, 18-19 May, National Center for Maps and Cartographic Heritage, Thessaloniki, ISBN: 960-7999-18-5, p. 87-91

Jenny B, Hurni L (2011) Studying cartographic heritage: Analysis and visualization of geometric distortions, Elsevier-Computers & Graphics, 35(2):402-411, http://cartography.oregonstate.edu/pdf/2011_Jenny_etal_GeometricDistortions.pdf Accessed 17 March 2013

Klöti, T (1997) Das Probeblatt zum "Atlas Suisse" (1796). Cartographica Helvetica 15-16:23-30. http://dx.doi.org/10.5169/seals-9072 Accessed 15 March 2013

Koussoulakou A, Tsorlini A, Boutoura C (2011) On the Generalkarte coverage of the northern part of Greece and its interactions with the relevant subsequent Greek map series, *e-Perimetron*, 6(1):46-56, http://www.e-perimetron.org/Vol_6_1/Koussoulakou_Tsorlini_Boutoura.pdf Accessed 15 March 2013

Livieratos E (2006) On the study of the geometric properties of historical cartographic representations, Cartographica, 41(2):165-175, http://utpjournals.metapress.com/content/rm863872894261p4/ Accessed 15 March 2013

Livieratos E (2006) A new ICA Working Group on merging cartographic heritage with digital technologies, welcome address at the First International Workshop on Digital Approaches to Cartographic Heritage, Thessaloniki, 18-19 May. http://xeee.web.auth.gr/ICA-Heritage/Commission/Introduction.pdf. Accessed 18 March 2013

Pearson A, Schaefer M, Jenny B (2008) The terrain models of Joachim Eugen Müller (1752-1833) and the production of the "Atlas Suisse par Meyer et Weiss". Proceedings of the 6th ICA Mountain Cartography Workshop Mountain Mapping and Visualisation, Lenk, Switzerland, p. 165-171. http://www.mountain-cartography.org/publications/papers/papers_lenk_08/pearson.pdf Accessed 18 March 2013

Tsioukas V., M. Daniil, E. Livieratos, 2006. “Possibilities and problems in close range non-contact 1:1 digitization of antique maps”, e-Perimetron, 1(3):230-238, http://www.e-perimetron.org/Vol_1_3/Tsioukas_Daniil_Livieratos.pdf Accessed 10 March 2013

Tsorlini A, Daniil M, Myridis M, Boutoura C (2010) An example of studying the evolution of a local geographic milieu in early 20th century Greece: Generalkarte (1900-1904) vs National mapping (1917) representations, 5th International Workshop Digital Approaches to Cartographic Heritage, Vienna, 22-24 February.

Wyder S (2007) Grenz- und Zentenpläne von Hans Conrad Gyger (1599-1674). Cartographica Helvetica 35-36:31-39. http://dx.doi.org/10.5169/seals-16709 Accessed 22 March 2013

The Relief Shading Website, http://www.reliefshading.com/history/gyger_zh.html Accessed 22 March 2013

The GeoHistory Portal powered by GeoVITe, Institute of Cartography and Geoinformation, ETH Zurich, Switzerland. https://geodata.ethz.ch/geohistory/

The GeoVITe Portal, Institute of Cartography and Geoinformation, ETH Zurich, Switzerland. https://geodata.ethz.ch/geovite/

The Federal Office of Topography (swisstopo) website, Bern, Switzerland, http://www.swisstopo.admin.ch/internet/swisstopo/en/home/swisstopo.html